An Aerial Survey for Muskoxen in the Inuvialuit Settlement Region and Tuktut Nogait National Park, 2002

John Nagy[1], Christian Bucher[2], and Wendy H. Wright[2]

[1]Environment and Natural Resources
Government of the Northwest Territories

[2]Tuktut Nogait National Park
Parks Canada Agency

2013

Manuscript Report No. 226

The contents of this report are the sole responsibility of the authors.

ABSTRACT

Tuktut Nogait National Park (TNNP) and the area west to the Kugaluk River in the Inuvialuit Settlement Region were surveyed during late winter/spring 2002. The non-calf muskox population estimate was 1,215 SE ± 526 (95% CI). This gave a density estimate of 0.015 non-calf muskoxen per km^2 in the survey area. A comparison of the mean non-calf population estimates did not differ significantly between years but suggested a possible decline of approximately 11% per year between 1997 and 2002. The reason for this decline is unknown but may be linked to increased predation by grizzly bears or an increase in predation risk resulting from lungworm infections. The results of our analyses support the view that the distribution of muskoxen in the ISR has shifted to the west during the past 30 - 35 years. During the late 1960s and 1970 most of the muskoxen sightings made were in TNNP or in adjacent areas to the west. By 2002 most of the muskoxen were observed in the Cape Bathurst Peninsula/Rendezvous Lake area.

TABLE OF CONTENTS

ABSTRACT ii

LIST OF FIGURES v

LIST OF TABLES vi

INTRODUCTION 1

Study Area 3

METHODS 4

Survey Design and Methods 4

Population Trends 9

Change in Distribution of Muskoxen 9

RESULTS 11

TNNP Survey Block 11

Block A, B, and C 11

Population Estimates 12

Population Trends 13

Change in Distribution of Muskoxen 15

Other Wildlife Observations 17

DISCUSSION 18

LITERATURE CITED 19

APPENDIX A: Weather Conditions at Paulatuk Airport Meteorological Station and Survey Activities, 27 to 29 March 2002 (Bucher 2002). 21

APPENDIX B: Number of Muskoxen Observed On and Off Transect In TNNP, 2002 (Bucher 2002). 22

APPENDIX C: Muskox Observed in the TNNP Survey Block, March 2002 (Bucher 2002). 23

APPENDIX D: Weather Conditions and Survey Activities During May 2002. 24

APPENDIX E: Number of Muskoxen Observed On and Off Transect in Survey Block A, May 2002. 25

APPENDIX F: Number of Muskoxen Observed On and Off Transect in Survey Block B, May 2002. 26

APPENDIX G: Number of Muskoxen Observed On and Off Transect in Survey Block C, May 2002. 27

APPENDIX H: Muskoxen Observed in Survey Blocks A, B, and C During May 2002. ...28

APPENDIX I: Caribou Observed During The Muskox Survey, May 2002. 29

APPENDIX J: Boreal Woodland Caribou Observed During The Muskox Survey, May 2002. 31

APPENDIX K: Golden Eagles Observed During The Muskox Survey, May 2002. 32

APPENDIX L: Grizzly Bears Observed During The Muskox Survey, May 2002. 33

APPENDIX M: Moose Observed During The Muskox Survey, May 2002. 34

APPENDIX N: Wolves Observed During The Muskox Survey, May 2002. 35

APPENDIX O: Wolverine Observed During The Muskox Survey, May 2002. 36

LIST OF FIGURES

Figure 1. The mainland ISR muskox survey study area, 2002. 2

Figure 2. Boundaries for muskox surveys completed in the area between Great Bear Lake and the Arctic coast in the NWT and Nunavut, 1980-1997) 3

Figure 3. Survey blocks and transect lines flown during the mainland ISR muskox survey, 2002 4

Figure 4. Groups sizes and sites where muskoxen were observed during the mainland ISR muskox survey, 2002 7

Figure 5. Population estimates for mainland ISR muskoxen, 1980-2002[A]. 13

Figure 6. Distribution of muskox sightings by decade in the eastern ISR, 1960s to 2000s. 15

Figure 7. Number of muskoxen observed in TNNP and survey blocks A, B, and C during surveys conducted in 1980, 1983, 1987, 1997, and 2002 16

LIST OF TABLES

Table 1. Population estimates for muskoxen in the Inuvialuit Settlement Region in 2002. 12

Table 2. Population estimates for muskoxen in the Inuvialuit Settlement Region in 1980, 1987, and 1997. 14

INTRODUCTION

Past muskox (*Ovibos moschatus*) surveys on the northern mainland of the Northwest Territories have varied in geographic scope but typically were centered in the area between the eastern Cape Bathurst Peninsula, western Tuktut Nogait National Park (TNNP), and Horton Lake (Figure 1) (Spencer 1980; Case and Poole 1985; McLean 1992; Larter 1999). Observations of muskox from hunters from Paulatuk and/or reconnaissance surveys were used to document the distribution of muskoxen in the area prior to the population surveys. Recent reports indicate that indigenous Canadian muskoxen (*Ovibos moschatus moschatus*) have expanded their range westward in the Inuvialuit Settlement Region (ISR) to the Husky Lakes area, and muskoxen introduced from Greenland (*Ovibos m. wardi*) continue to expand their range eastward into the Northwest Territories (NWT) from Alaska and the North Slope of the Yukon. One "North Slope" bull and a group of 15 muskoxen (bulls, cows and calves) were observed in Parson's Lake area in February 2001 and May 2001, respectively by hunters from Inuvik. As a result, the potential of these two groups to interbreed increases as does the potential for the transmission of the muskox lungworm (*Umingmakstrongylus pallikuukensis*) into muskoxen on the North Slope, Yukon Territories (Kutz et al. 2001, Kutz et al. 2004).

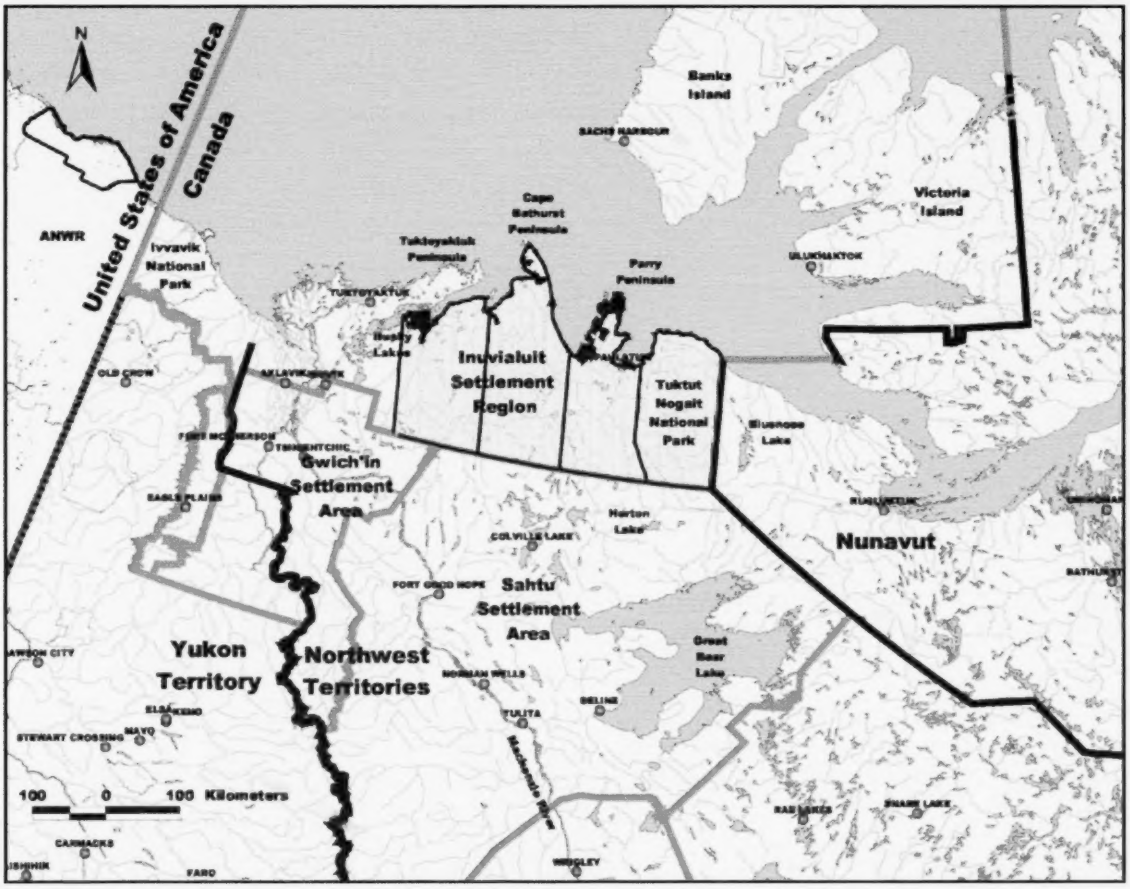

Figure 1: The mainland ISR muskox survey study area, 2002.

This survey was undertaken to address the following:

- to determine the status of the muskox population within the mainland portion of the ISR and TNNP, and
- to document the western extent of the distribution of indigenous Canadian muskoxen in the ISR.

This report documents the results of surveys conducted cooperatively by the Parks Canada Agency (Paulatuk, NWT) during late March 2002 (Bucher 2002) and the Department of Environment and Natural Resources (ENR) in the ISR east of the Kugaluk River and to the western boundary of TNNP during early May 2002.

Study Area

The study area totals 79,901 km^2 and included TNNP and the area west to the Kugaluk River in the ISR, NWT (Figure 2). The survey area excludes the frozen offshore waters in the Cape Bathurst and Parry Peninsula areas.

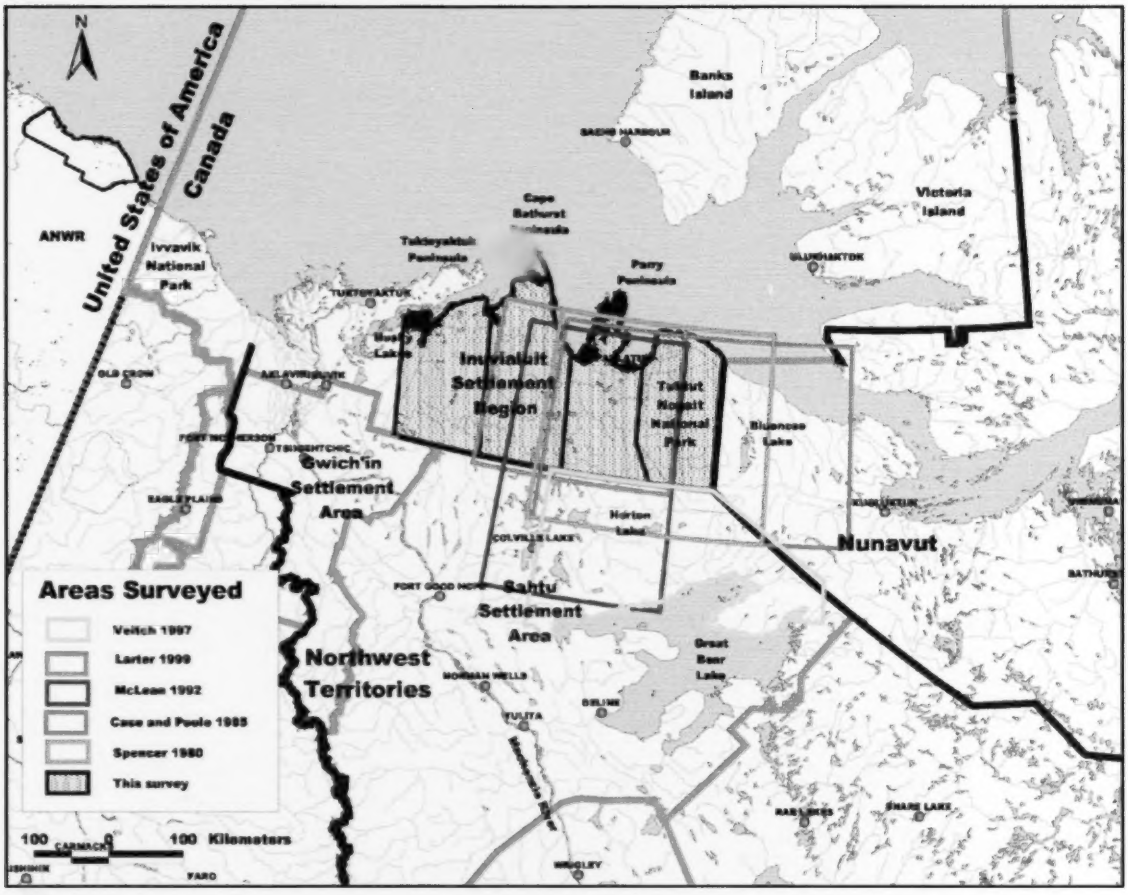

Figure 2: Boundaries for muskox surveys completed in the area between Great Bear Lake and the Arctic coast in the NWT and Nunavut, 1980-1997).

METHODS

Survey Design and Methods

The survey area was divided into four blocks (Figure 3). Transects were oriented to intersect major river drainage systems at right angles to minimize over-sampling of preferred habitats. Ninety-five transects, spaced 10 km apart, provided 10% coverage. Waypoints for the ends of all transect were generated using ArcView (Environmental Systems Research Institute).

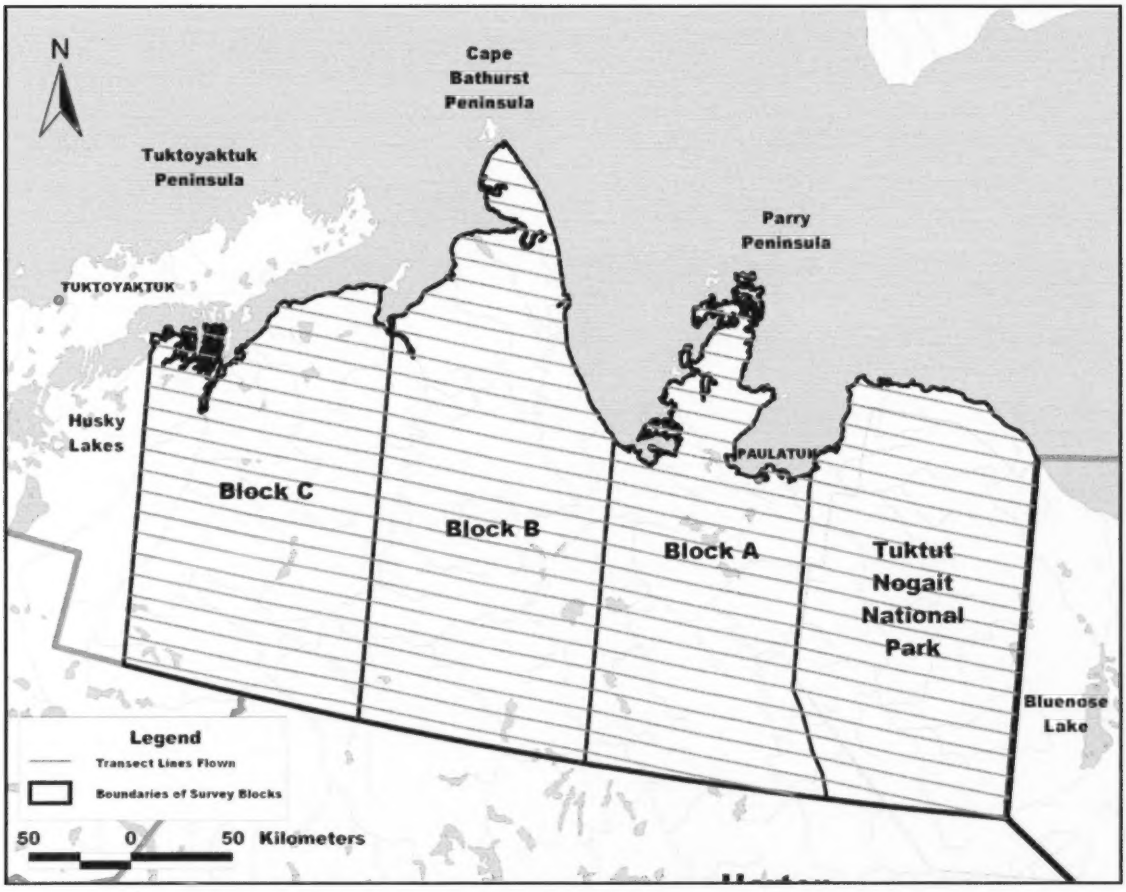

Figure 3: Survey blocks and transect lines flown during the mainland ISR muskox survey, 2002.

The survey crews comprised a pilot, two observers seated in the back seat of the Helio Courier aircraft, and a recorder seated in the right front seat. Survey crews were equipped with a laptop computer with OziExplorer (OziExplorer GPS Mapping Software), a digital map of the survey area, and the digital transect waypoint database installed. Each day we used OziExplorer to download the waypoints of the transect end points from the laptop to the GPS of the aircraft. The pilot used these waypoints to navigate to the start and end points of each transect using the GPS of the aircraft. TNNP was surveyed at a flight altitude of 132 m and average speed of 170 km/hr. Transects 1 to 10 in Block C were flown at a survey altitude of 132 m and average speed of 160 km/hr. The remainder of Block C and Blocks A and B were flown at a survey altitude of 110 m and average speed of 160 km/hr.

Muskoxen were counted within and outside of the boundaries of a 500 m wide strip on each side of the aircraft. Strip width was marked using a tape marker on a wire stretched between the tie-down rings and the fuselage using the formula:

$$w = W \times h + H$$

where w is the calculated strip width on the ground, W is the chosen survey strip width, h is the height of the observer on the ground, and H is the chosen survey altitude (Norton-Griffiths 1987). All sightings of other wildlife (caribou, moose, wolves, and wolverine) were recorded.

The recorder had a GPS equipped with an external antenna mounted on the wind screen of the aircraft. The recorder created a waypoint for each observation and recorded the number of the waypoint and the number and types of muskoxen or other wildlife at each waypoint. At the end of each day the waypoint files were downloaded to the laptop computer. The files were then imported into Microsoft Excel and the waypoint coordinate data (number, latitude and longitude coordinates, date and time) were appended to the observation data. We used the GPS to create a track file of all transects

flown (location recorded every 30 seconds). The track files were downloaded to the laptop computer at the end of each flight.

Muskoxen were classified as adults (age ≥ 1 year) and calves. Observers were equipped with binoculars to help ensure that counts and classifications were done accurately. If an observer had difficulty, the pilot flew the aircraft off transect and flew in a tight circle around the muskoxen, so that an accurate count and classification could be done. The pilot then flew the aircraft back to the transect line and the survey resumed.

The waypoints and track files for all observations made along each transect line within each block were mapped using OziExplorer. All observations that were recorded before the starting point and after the end point of each transect were deleted. Only muskoxen that were observed off transect between transect lines within a survey block were included in the analyses (Figure 4). This was done to minimize the probability of including individuals or groups of muskoxen in the analyses more than once. The numbers of non-calf and calf muskoxen observed on and off transect for all transects were summarized using Microsoft Excel. The length of each transect was derived using the waypoints for the start and end of each transect and the route function in OziExplorer.

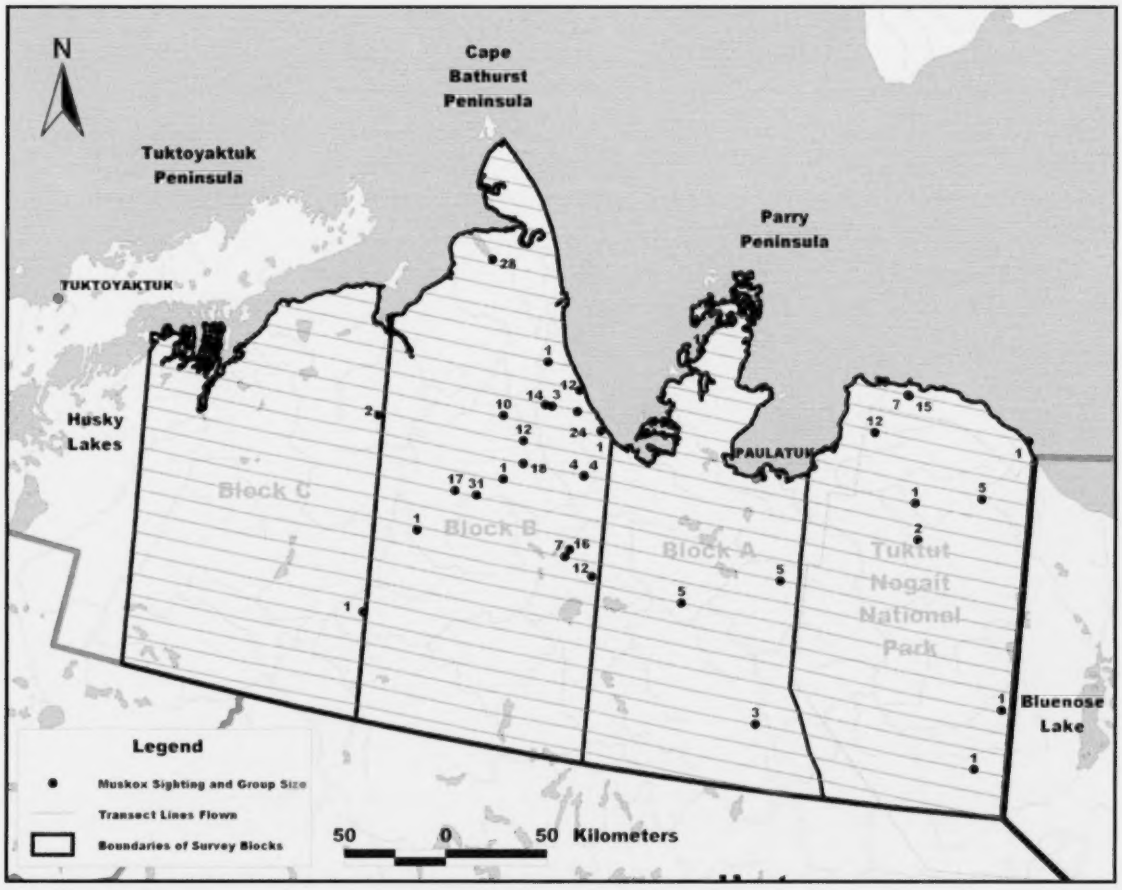

Figure 4: Groups sizes and sites where muskoxen were observed during the mainland ISR muskox survey, 2002.

The population estimates and associated statistics were calculated using the Aerial 2 version 3.0 method 2 (Krebs 1999). Estimates for non-calf, calf, and all muskoxen were derived for each survey block. Population and variance estimates from each stratum were combined to derive an overall population and population variance estimate for non-calf, calf, and all muskoxen, respectively, in all survey blocks.

The estimation of population number and variance from stratified surveys is given in Compton (1995) cited in Johnson et al. (2004). The total population number is the summation of individual stratum estimates (equation 1):

$$\hat{N}_{total} = \sum_{h=1}^{L} \hat{N}_h$$

where there are L strata units. Assuming that the selection of sample units within each stratum is independent of other strata units, the variance is estimated as the sum of individual variance estimates for each stratum (equation 2):

$$\mathrm{var}_{total} = \sum_{h=1}^{L} \mathrm{var}_h$$

Confidence intervals for the population estimate can be approximated by (equation 3):

$$\hat{N}_{total} \pm t\sqrt{\mathrm{var}_{total}}$$

The degrees of freedom (d) for the t-statistic can be approximated by the following formula (equation 4):

$$d = \frac{\left(\sum_{h=1}^{L} a_h s_h^2\right)^2}{\left[\sum_{h=1}^{L}\left(\left.(a_h s_h^2)^2\right/(n_h - 1)\right)\right]}$$

where $a_h = N_h(N_h - n_h)/n_h$, where N_h is the possible number of transects in an individual block and n_h is the actual number of transects flown. The sample variance from each block is denoted as s^2 in the above formula, and L is the total number of strata (Compton et al. 1995). This assumes that the population estimates and variance estimates from each stratum are unbiased and independent.

We used a two-tailed t-test to determine whether the estimates of the non-calf muskoxen in 2002 were significantly different from those in 1997. We calculated the t-statistic (t^2) using the following formula (Gasaway et al. 1986:62) (equation 5):

$$t^2 = T_{2002} - T_{1997} / [V(T_{2002} + V(T_{1997})]^{0.5}$$

where:

- T_{2002} and T_{1997} = population estimates of non-calf and calf muskox from surveys in 2005 and 2001, respectively; and

- $V(T_{2002})$ and $V(T_{1997})$ = variances of population estimates of non-calf and calf muskoxen from surveys in 2005 and 2001, respectively.

We used the following formula to estimate the total degrees of freedom (v_t) associated with the t-statistic (Gasaway et al. 1986:62) (equation 6):

$$[V(T_{2002})+V(T_{1997})]^2/\{[V(T_{2002})^2/v_{o2002}]+[V(T_{1997})^2/v_{o1997}]\}$$

where:

- $V(T_{2002})$ and $V(T_{1997})$ = variances of population estimates of non-calf and calf muskox from surveys in 2005 and 2001, respectively
- v_{o2002} and v_{o1997} = degrees of freedom from surveys in 2005 and 2001, respectively (derived from equation 4).

Maps showing the distribution of muskoxen observed on and off transect were created using ArcView.

Population Trends

Spencer (1980), McLean (1992), and Larter (1999) either provided sufficient information in their reports that we were able to identify and re-analyze data for survey blocks that fell within the ISR, or the original field survey data were on file in the ENR Inuvik Region office so that we were able to re-analyze data for survey blocks that fell within the ISR. We then derived population estimates for these data using the methods describe above.

Change in Distribution of Muskoxen

We created a digital database of sightings of muskoxen made on the eastern mainland of the ISR including sightings made during muskox surveys (Spencer 1980; Case and Poole 1985; McLean 1992; Veitch 1997; Larter 1999; Bucher 2002), other surveys (Thomas 1969; Hawley et al. 1979; Brackett et al. 1982; Williams and Elliott 1985), and sightings made by ENR and Parks Canada staff (N. Larter, J. Nagy, M.

Theberge, and P. Voudrach, among others). Whenever possible, we derived latitude and longitude coordinates from sightings recorded on the original field survey maps. We categorized and mapped the observations by decade to visually assess changes in distribution. We extracted sightings made during surveys done in 1980 (Spencer 1980), 1983 (Case and Poole 1985), 1987 (McLean 1992), 1997 (Larter 1999), and 2002 (this survey) for each survey block (TNNP and blocks A, B, and C). Observations made during these surveys were excluded if coverage of a block was not complete. The 1980 survey was flown at 6% coverage while the remaining surveys were flown at 10% coverage. These observations were used as an index of the relative change in abundance and distribution of muskoxen within the 2002 survey area between 1980 and 2002.

RESULTS

TNNP Survey Block

The survey of the TNNP block was completed in three days during 27 - 29 March 2002. Total flight time was 18.6 hours, including ferry time to and from Paulatuk and various transect locations. Weather conditions during the survey were generally good with sunny, clear skies, very good visibility, and extremely cold temperatures (Appendix A).

Nine sightings of muskoxen were made during the survey, including 43 adults and two yearlings (2001 calves) (Appendix B and C). Fourteen adults and one yearling (2001 calf) were observed on transect; 18 adults and one yearling (2001 calf) were observed off transect. Total transect area was 2,068 km^2 (Appendix B). Yearlings comprised 4.4% of all muskoxen observed during the survey. TNNP was surveyed in late winter prior to calving.

Block A, B, and C

The survey of blocks A, B, and C was completed in eight days of flying during 5 - 13 May 2002. The area could not be flown earlier due to poor weather conditions. Total flight time was 63.8 hours, including 20.7 hours of ferry time to and from Inuvik or Rendezvous Lake and various transect locations (Appendix D). Weather conditions during the survey were generally good with sunny, clear skies, very good visibility, and good to excellent contrast (Appendix D). There was 100% snow cover on areas surveyed 5 - 12 May. Snow cover had been reduced to approximately 85% to 90% cover in portions of areas surveyed on 13 May.

Twenty-four sightings of muskoxen were made during the survey, including 188 adults and 30 calves (born 2002) (Appendix E, F, G, and H). A total of 122 adults and 15 calves were observed on transect; 66 adults and 15 calves were observed off transect. Total transect area was 6,416.1 km^2. Yearlings comprised 1.1% of all muskoxen observed during the survey.

Survey blocks A, B, and C were surveyed after the peak of calving. We observed a total of 188 non-calf and 30 calf muskoxen in these survey blocks or 15.9 calves per 100 non-calf muskoxen.

Population Estimates

The statistical parameters for the estimates of the number of non-calf muskoxen in the TNNP, A, B, and C survey blocks are provided in Table 1. The non-calf muskox population estimate was 1,215 SE ± 526 (95% CI); this gave a density estimate of 0.015 non-calf muskoxen per km^2 (Table 1).

Table 1: Population estimates for muskoxen in the Inuvialuit Settlement Region in 2002.

Survey Block	Census Area (km^2)	Number of Transects Flown	Number of Possible Transects	Density (per km^2)	Population Total	Variance of Totals	S.E. of Y	95% Confidence Interval (±)	% of Total Area Sampled	Number On Transect	Number Off Transect	Coefficient Of Variation	df
Non-calf													
A	16,934	25	152	0.016	264	8,755.8	93.6	193	10.6	38	1	0.355	
B	23,847	28	177	0.034	801	48,961.6	221.3	454	10.5	84	63	0.276	
C	19,718	22	136						10.7	0	2		
TNNP	19,402	20	125	0.008	150	7,649.1	87.5	183	10.7	15	19	0.583	
Sum of blocks	79,901	95	590	0.015	1,215	65,366.5	255.7	526	10.7	137	85	0.210	27
Calf													
A	16,934	25	152	0.002	28	296.5	17.2	36	10.6	3	0	0.610	
B	23,847	28	177	0.005	114	1,944.3	44.1	90	10.5	12	15	0.385	
C	19,718	22	136						10.7	0	0		
TNNP	19,402	20	125						10.7	0	0		
Sum of blocks	79,901	95	590	0.002	143	2,240.9	47.3	97	10.7	15	15	0.332	27
Total													
A	16,934	25	152	0.017	292	11,972.3	109.4	226	10.6	41	1	0.375	
B	23,847	28	177	0.038	916	67,254.8	259.3	532	10.5	96	78	0.283	
C	19,718	22	136						10.7	0	2		
TNNP	19,402	20	125	0.008	150	7,649.1	87.5	183	10.7	15	19	0.583	
Sum of blocks	79,901	95	590	0.017	1,358	86,876.2	294.7	606	10.7	152	100	0.217	27

Population Trends

Spencer (1980) survey blocks A, B, and C fell within the ISR. Spencer (1980) estimated that there were 3,290 ± 1,969 non-calf muskoxen in these areas (Table 2 and Figure 5). McLean (1992) transect lines 1 to 15 fell within the ISR; analysis of the data for these lines gave an estimate of 2,968 ± 4,173 non-calf muskoxen (Table 2 and Figure 5). (Larter 1999) found approximately 2,567 ± 1,505 non-calf muskoxen in the area (Table 2 and Figure 5).

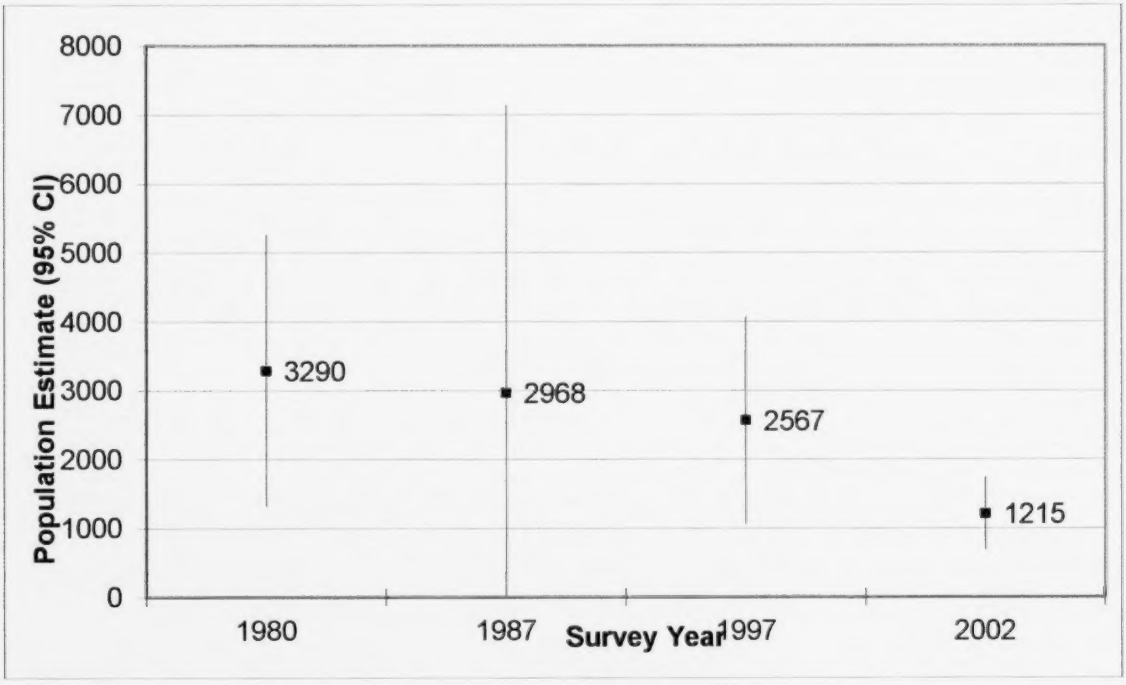

Figure 5: Population estimates for mainland ISR muskoxen, 1980-2002.[1]

[1] Data obtained from the following sources: 1980 (Spencer, 1980); 1987 (McLean, 1992); 1997 (Larter, 1999); 2002 (this report).

Table 2: Population estimates for muskoxen in the Inuvialuit Settlement Region in 1980, 1987, and 1997.

Survey Block	Census Area (km^2)	Number of Transects Flown	Number of Possible Transects	Density (per km^2)	Population Total	Variance of Totals	S.E. of Y	95% Confidence Interval (±)	% of Total Area Sampled	Number On Transect	Number Off Transect	Coefficient Of Variation	df
Spencer (1980)													
Non-calf													
A	1,604	8	64	0.333	535	34,149.3	184.8	437	11.0	59	not recorded	0.346	
B	10,182	10	80	0.271	2,756	695,023.0	833.7	1,886	12.1	332	not recorded	0.303	
Sum of blocks	11,786	18	144	0.279	3,290	729,172.2	853.9	1,969	11.9	391	0	0.260	9
Mclean (1987)													
Non-calf	27,758	15	231	0.107	2,968	3,784,410.9	1945.4	4,173	10.0	297	not recorded	0.656	14
Calf	27,758	15	231	0.013	350	67,645.3	260.1	558	10.0	35	not recorded	0.744	14
Total	27,758	15	231	0.120	3,317	4,792,086.2	2189.1	4,696	10.0	332	not recorded	0.660	14
Larter (1997)													
Non-calf	36,730	22	220	0.070	2,567	523,649.3	723.6	1,505	9.9	253	133	0.282	21
Calf	36,730	22	220	0.009	335	11,363.0	106.6	222	9.9	33	10	0.318	21
Total	36,730	22	220	0.079	2,902	680,859.8	825.1	1,716	9.9	286	143	0.284	21

Population estimates derived by McLean (1992) ($t^2 = 0.152$, DF = 19, $P>0.05$) and Larter (1999) ($t^2 = 0.647$, DF = 22, $P>0.05$) were not significantly different than that reported by Spencer (1980). Similarly, the population estimate derived by Larter (1999) was not significantly different from that reported by McLean (1992) ($t^2 = 0.193$, DF = 18, $P>0.05$). Our population estimate was significantly lower than that reported by Spencer (1980) ($t^2 = 2.328$, DF = 11, $P<0.05$), but not significantly different from those reported by McLean (1992) ($t^2 = 0.893$, DF = 14, $P>0.05$) and Larter (1999) ($t^2 = 1.761$, DF = 26, $P>0.05$). A comparison of mean population estimates (Figure 5) suggests that the finite rate of growth (Caughley 1980) for the muskox population was −53% during the period 1997 and 2002.

Change in Distribution of Muskoxen

The distribution of muskoxen sightings recorded during the period 1967 to 2004 was colour-coded by decade (Figure 6). These data suggest a westward shift in the distribution of muskoxen within the ISR. During the 1970s most of the sightings occurred in and adjacent to TNNP, while in the 1980s most of the muskox sightings were made in the area directly south of Parry Peninsula. By the 1990s and early 2000s most of the sightings were made on the Cape Bathurst Peninsula and south to the Rendezvous Lake area.

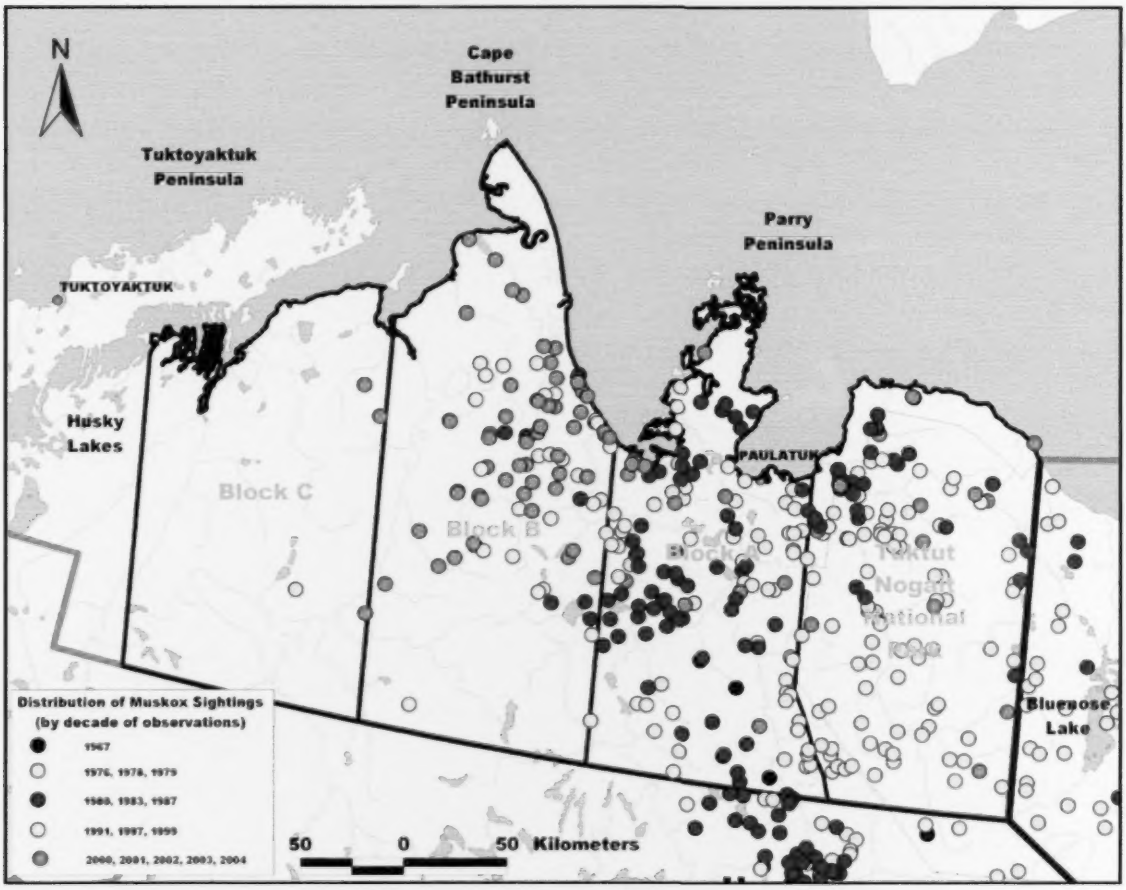

Figure 6: Distribution of muskox sightings by decade in the eastern ISR, 1960s to 2000s.

The relative abundance of muskoxen in TNNP and survey blocks A to C (east to west) is shown in Figure 7. Most of the muskoxen observed during the 1980 survey (Spencer 1980) were in TNNP and survey block A. By 2002, most of the muskoxen observed during the survey (this report) were found in survey blocks B and C. These data also support the view that there has been a westward shift in the distribution of muskoxen within the ISR.

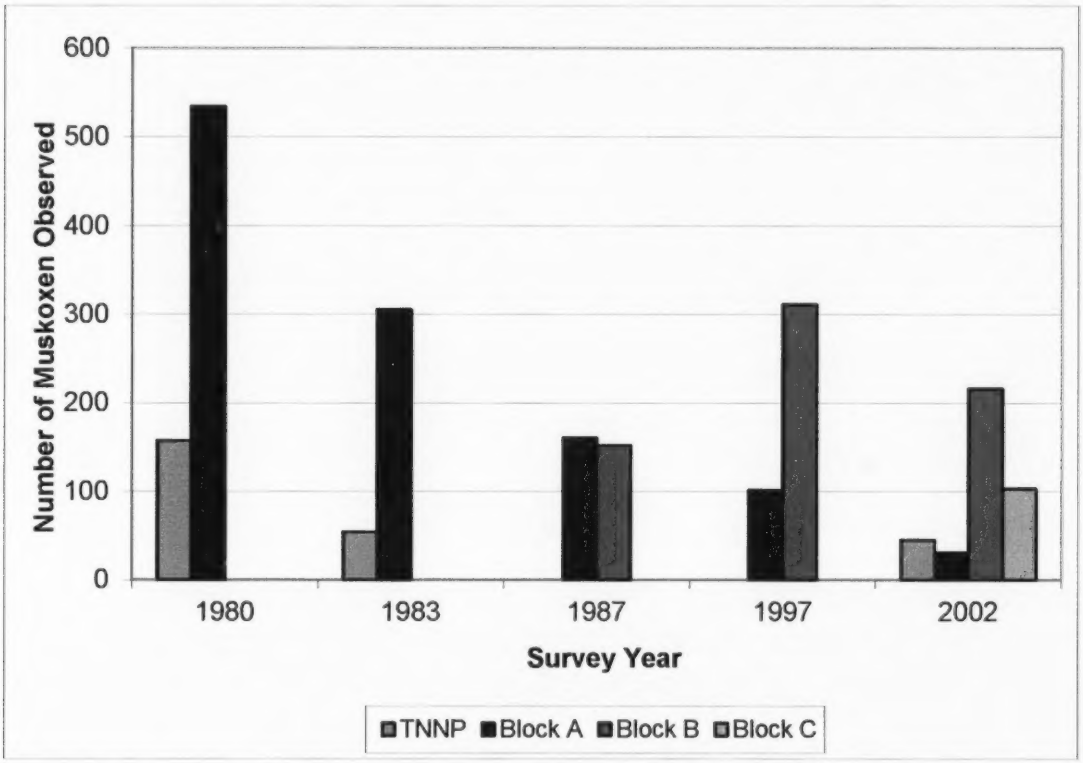

Figure 7: Number of muskoxen observed in TNNP and survey blocks A, B, and C during surveys conducted in 1980, 1983, 1987, 1997, and 2002.[2]

[2] Data sources and coverage as follows:
1980 survey coverage 6% (Spencer, 1980); 1983 survey coverage 10% (Case and Poole, 1985); 1987 survey coverage 10% (McLean, 1992); 1997 survey coverage 10% (Larter ,1999); 2002 survey coverage 10% (this survey).

Other Wildlife Observations

Other wildlife observations included 7,057 barren-ground caribou (Appendix I), 14 boreal woodland caribou (Appendix J), four golden eagles (Appendix K), 20 grizzly bears (Appendix L), five moose (Appendix M), two wolves (Appendix N), and four wolverines (Appendix O). Red foxes were observed during the survey but were not consistently recorded.

DISCUSSION

The geographic scope of surveys completed to estimate numbers of muskoxen on the northern mainland, NWT has varied. To determine population trend we analyzed the data obtained by Spencer (1980) and McLean (1992) to estimate the number of muskoxen in the ISR in 1980 and 1987, respectively. The 1997 (Larter 1999) and 2002 (this report) survey areas were completely within the ISR. Our analyses indicate that the 1980, 1987, and 1997 population estimates for non-calf muskoxen were not significantly different; however, a comparison of mean population estimates suggests a possible decline of approximately 1% per year between 1980 and 1997. Similarly, the 1987, 1997, and 2002 population estimates were not significantly different; however, a comparison of the mean population estimates suggests a possible decline of approximately 11% per year between 1997 and 2002. The reason for this decline is unknown but may be linked to increased predation by grizzly bears or an increase in predation risk resulting from lungworm infections.

The results of our analyses support the view that the distribution of muskoxen in the ISR had shifted to the west during the past 30 - 35 years. During the late 1960s and 1970 most of the muskoxen sightings made were in TNNP or in adjacent areas to the west. By 2002 most of the muskoxen were observed in the Cape Bathurst Peninsula/Rendezvous Lake area.

LITERATURE CITED

Brackett, D., W. Spencer, and E. Hall. 1982. Bluenose caribou surveys, 1978-1979. NWT Wildlife Service, Government of the Northwest Territories. File Report No. 24. 22pp.

Bucher, C. 2002. An aerial survey of muskoxen in Tuktut Nogait National Park of Canada March 2002. Tuktut Nogait National Park of Canada, Parks Canada Agency, Paulatuk, NWT. Data Report TNNP 01/02 Internal Report. 20pp.

Case, R.L. and K.G. Poole. 1985. Distribution, abundance and composition of muskoxen north of Great Bear Lake, March 1983. NWT Wildlife Service, Government of the Northwest Territories, Yellowknife, NT. File Report No. 51. 48pp.

Caughley, G. 1977. Analysis of Vertebrate Populations. Wiley, London., and LC Birch. 1971. Rate of increase. J. Wildl. Manage. 35(4): 658-663.

Compton, B.B., P. Zager and G. Servheen. 1995. Survival and mortality of translocated woodland caribou. Wildlife Society Bulletin 23:490-496 *In* C.J. Johnson, K.L. Parker, D.C. Heard and D.R. Seip. 2004. Movements, foraging habits, and habitat use strategies of northern woodland caribou during winter: implications for forest practices in British Columbia. BC Journal of Ecosystems and Management 5: 22-35.

Environmental Systems Research Institute. ArcView GIS: Release 3.2 [software], 1992-1999. Environmental Systems Research Institute, Redlands, CA.

Gasaway, W.C., S.D. Dubois, D.J. Reed, and S.J. Harbo. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska 22:108.

Hawley, V., D. Poll, and R. Brown. 1979. The Bluenose caribou herd, 1974-1976. Canadian Wildlife Service. Edmonton, Alberta. Draft report. 113pp.

Krebs, C.J. 1999. Ecological Methodology, 2nd edition. Benjamin Cummings, San Francisco, CA.

Kutz, S.J., E.P. Hoberg, J. Nagy, L. Polley, and B. Elkin. 2004. "Emerging" parasitic infections in arctic ungulates. Integrative and Comparative Biology 44: 109-118.

Kutz, S.J., E.P. Hoberg, and L. Polley. 2001. A new lungworm in muskoxen: an exploration in arctic parasitology. Trends in Parasitology 17: 276-280.

Larter, N.C. 1999. An aerial survey of muskoxen in the Paulatuk area of the Inuvialuit Settlement Region, March 1997. Department of Resources, Wildlife, and Economic Development, Government of the Northwest Territories, Inuvik, NWT. Manuscript Report No. 116. 27pp.

McLean, B.D. 1992. An aerial survey of muskoxen north of Great Bear Lake, August, 1987. Department of Renewable Resources, Government of the Northwest Territories, Inuvik, NWT. File Report No. 103. 19 pp.

Norton-Griffiths, M. 1987. Counting animals: Serengetti ecological monitoring program handbook No. 1. African Wildlife Leadership Foundation. Nairobi, Kenya. 110pp.

OziExplorer GPS Mapping Software. Version 3.95.4m, Aug. 18, 2004. D&L Software Pty Ltd., Brisbane, Australia.

Spencer, W. 1980. Muskox (*Ovibos moschatus*) survey Paulatuk, NWT March 8-17, 1980. NWT Wildlife Service, Government of Northwest Territories Report. 26pp.

Thomas, D.C. 1969. Population estimates of barren-ground caribou March to May, 1967. Canadian Wildlife Service Report Series No. 9: 44.

Veitch, A.M. 1997. An aerial survey for muskoxen in the northern Sahtu Settlement Area, March 1997. Department of Resources, Wildlife, and Economic Development, Government of the Northwest Territories, Norman Wells, NWT. Manuscript Report No. 103. 42pp.

Williams, T.M. and C. Elliott. 1985. Spring classification counts on the Bluenose caribou herd March, 1983. Department of Renewable Resources, Government of the Northwest Territories, Yellowknife, NWT. File Report No. 58. 26pp.

APPENDIX A: Weather Conditions at Paulatuk Airport Meteorological Station and Survey Activities, 27 to 29 March 2002 (Bucher 2002).

Date	Weather conditions	Hours flown		Transects flown
		Total	On survey	
27 March	Fog in AM; ice crystals in PM; -34 to –39 °C; relative humidity 89 to 92; wind W11 to 19 kph; wind chill -47 to –54 (extreme)	3:52	1:55	T01 to T03
28 March	Ice crystals in AM; sunny late AM and PM; -33 to – 37 °C; relative humidity 71 to 93; wind SW 11 to 15 kph; wind chill -45 to -49 (cold to extreme)	7:01	6:02	T04 to T11
29 March	Ice crystals; -28 to –31 °C; relative humidity 75 to 87; wind S or SW 28 to 31 kph; wind chill -43 to -48 (cold to extreme)	8:04	7:00	T12 to T20
	Total	18:57	14:58	

APPENDIX B: Number of Muskoxen Observed On and Off Transect In TNNP, 2002 (Bucher 2002).

		On transect			Off transect		
Transect No.	Area (km^2)	Adults	Calves[1]	Total	Adults	Calves[1]	Total
1	91.13	0	0	0	0	0	0
2	97.00	0	0	0	0	0	0
3	101.25	0	0	0	1	0	1
4	104.97	0	0	0	0	0	0
5	109.88	0	0	0	0	0	0
6	109.86	0	0	0	1	0	1
7	110.23	0	0	0	0	0	0
8	109.80	0	0	0	0	0	0
9	110.57	0	0	0	0	0	0
10	110.53	0	0	0	0	0	0
11	110.48	0	0	0	0	0	0
12	110.44	0	0	0	0	0	0
13	110.38	0	0	0	2	0	2
14	109.93	0	0	0	0	0	0
15	110.27	1	0	1	0	0	0
16	109.42	0	0	0	5	0	5
17	97.58	0	0	0	0	0	0
18	96.79	0	0	0	11	1	12
19	89.03	0	0	0	1	0	0
20	68.00	14	1	15	7	0	7
Total	2,067.54	15	1	16	28	1	29

[1] Calves born in spring 2001.

APPENDIX C: Muskox Observed in the TNNP Survey Block, March 2002 (Bucher 2002).

Date	Latitude	Longitude	Transect	Observation	On/Off	Adult	Calf	Total
27-Mar-02	68.20	-121.07	TNNP 03	1	off	1	0	1
28-Mar-02	68.46	-120.81	TNNP 06	2	off	1	0	1
29-Mar-02	69.15	-122.02	TNNP 13	3	off	2	0	2
29-Mar-02	69.31	-122.10	TNNP 15	4	on	2	0	2
29-Mar-02	69.36	-121.28	TNNP 16	5	off	5	0	5
29-Mar-02	69.59	-122.70	TNNP 18	6	off	11	1	12
29-Mar-02	69.62	-120.77	TNNP 19	7	off	1	0	1
29-Mar-02	69.77	-122.34	TNNP 20	8	on	14	1	15
29-Mar-02	69.76	-122.33	TNNP 20	9	off	7	0	7

Other wildlife observations included one red fox, two wolverines, one polar bear, and seven caribou.

APPENDIX D: Weather Conditions and Survey Activities During May 2002.

Date	Survey base	Weather Inuvik or Rendezvous Lake	Hours flown		Transects flown
			Total	On survey	
05 May flight 1	Inuvik	CAVU*; light wind, -8°C	6:00	4:29	C01 to C06
05 May flight 2	Inuvik	CAVU; light wind, -8°C	4:24	3:07	C07 to C10
06 May	Inuvik	CAVU; wind 11 nm, -5 °C	6:48	4:29	C11 to C16
07 May	Inuvik	CAVU; wind 11 nm, -5 °C	7:10	4:30	C17 to C22 B23 to B28
08 May flight 1	Inuvik	CAVU; wind 11-15 nm, 0 °C	1:30		Flight to Rendezvous Lake
08 May flight 2	Rendezvous Lake	CAVU; light wind, 0 to +5 °C	3:26	3:04	B07 to B10
09 May flight 1	Rendezvous Lake	High overcast, calm, +5 °C	5:46	4:34	B01 to B06
09 May flight 2	Rendezvous Lake	High overcast, calm, +5 °C	3:26	3:04	B11 to B16
10 May	Rendezvous Lake	Low overcast, calm, +5 °C	6:14	4:39	A01 to A06
11 May	Rendezvous Lake	Fog, rain, calm, , 0 to +2 °C			
12 May flight 1	Rendezvous Lake	High overcast, light wind, 0 to +2 °C	3:14	2:28	A07 to A10 (E ends in fog)
12 May flight 2	Rendezvous Lake	High overcast, light wind, 0 to +2 °C	3:23	2:41	A11 to A14
13 May flight 1	Rendezvous Lake	CAVU, light wind, 0 °C	1:45	0:20	A07 to A10 (ends)
13 May flight 2	Paulatuk	CAVU, wind 15-20 nm, 0 °C	4:18	3:06	A15 to A25 (W end of A15 in fog)
13 May flight 3	Paulatuk	CAVU, wind 15-20 nm, 0 °C	6:24	2:32	A15 (end) B17 to B22
		Total	63.8	43.1	

*CAVU – Clear and visibly unlimited

APPENDIX E: Number of Muskoxen Observed On and Off Transect in Survey Block A, May 2002.

Transect No.	Area (km^2)	On transect			Off transect		
		Adults	Calves	Total	Adults	Calves	Total
1	103.9	0	0	0	0	0	0
2	118.1	0	0	0	0	0	0
3	112.7	0	0	0	0	0	0
4	108.0	3	0	3	0	0	0
5	104.3	0	0	0	0	0	0
6	99.0	0	0	0	0	0	0
7	99.0	0	0	0	0	0	0
8	98.2	0	0	0	0	0	0
9	98.6	5	0	5	0	0	0
10	98.2	0	0	0	0	0	0
11	98.2	5	0	5	0	0	0
12	98.2	0	0	0	0	0	0
13	98.2	0	0	0	0	0	0
14	98.2	0	0	0	0	0	0
15	98.2	0	0	0	1	0	1
16	47.6	0	0	0	0	0	0
17	43.5	0	0	0	0	0	0
18	39.5	0	0	0	0	0	0
19	47.5	0	0	0	0	0	0
20	17.0	0	0	0	0	0	0
21	24.6	15	3	18	0	0	0
22	19.2	0	0	0	0	0	0
23	20.5	0	0	0	0	0	0
24	5.0	0	0	0	0	0	0
25	2.8	0	0	0	0	0	0
Total	1,798.2	28	3	31	1	0	1

APPENDIX F: Number of Muskoxen Observed On and Off Transect in Survey Block B, May 2002.

Transect No.	Area (km^2)	On transect			Off transect		
		Adults	Calves	Total	Adults	Calves	Total
1	112.8	0	0	0	0	0	0
2	112.8	0	0	0	0	0	0
3	113.1	0	0	0	0	0	0
4	113.1	0	0	0	0	0	0
5	113.1	0	0	0	0	0	0
6	112.6	0	0	0	0	0	0
7	112.6	0	0	0	0	0	0
8	113.0	0	0	0	0	0	0
9	112.9	0	0	0	0	0	0
10	112.8	0	0	0	0	0	0
11	112.8	0	0	0	0	0	0
12	113.1	16	1	17	22	9	31
13	113.1	0	0	0	1	0	1
14	113.0	4	0	4	14	4	18
15	112.9	12	0	12	0	0	0
16	112.8	7	3	10	0	0	0
17	104.5	34	7	41	0	0	0
18	97.1	10	2	12	0	0	0
19	90.1	1	0	1	0	0	0
20	80.0	0	0	0	0	0	0
21	70.5	0	0	0	0	0	0
22	60.2	0	0	0	0	0	0
23	54.2	0	0	0	26	2	28
24	49.8	0	0	0	0	0	0
25	18.2	0	0	0	0	0	0
26	24.4	0	0	0	0	0	0
27	27.4	0	0	0	0	0	0
28	16.4	0	0	0	0	0	0
Total	2,499.7	84	13	97	63	15	78

APPENDIX G: Number of Muskoxen Observed On and Off Transect in Survey Block C, May 2002.

Transect No.	Area (km^2)	On transect			Off transect		
		Adults	Calves	Total	Adults	Calves	Total
1	117.5	0	0	0	0	0	0
2	117.4	0	0	0	0	0	0
3	117.4	0	0	0	0	0	0
4	117.3	0	0	0	0	0	0
5	117.3	0	0	0	0	0	0
6	117.6	0	0	0	0	0	0
7	117.6	0	0	0	0	0	0
8	117.5	0	0	0	0	0	0
9	117.5	0	0	0	0	0	0
10	117.4	0	0	0	0	0	0
11	117.4	0	0	0	0	0	0
12	117.3	0	0	0	0	0	0
13	117.2	0	0	0	0	0	0
14	117.1	0	0	0	0	0	0
15	117.4	0	0	0	2	0	2
16	116.2	0	0	0	0	0	0
17	85.7	0	0	0	0	0	0
18	62.0	0	0	0	0	0	0
19	57.9	0	0	0	0	0	0
20	26.7	0	0	0	0	0	0
21	4.8	0	0	0	0	0	0
22	4.0	0	0	0	0	0	0
Total	2,118.2	0	0	0	2	0	2

APPENDIX H: Muskoxen Observed in Survey Blocks A, B, and C During May 2002.

Date and Time	Lat	Long	Transect	On/Off	Lt/Rt	Adults	Yearlings	Calves	Total
5/6/02 4:48 PM	69.30	-128.85	C15	off	rt	1	1	0	2
5/7/02 5:18 PM	70.06	-127.84	B23	off	rt	26	0	2	28
5/9/02 1:03 PM	68.46	-128.53		off	rt	1	0	0	1
5/9/02 4:46 PM	69.05	-127.73	B12	on	lt	16	0	1	17
5/9/02 4:50 PM	69.05	-127.46	B12	off	rt	22	0	9	31
5/9/02 5:42 PM	69.14	-127.18	B13	off	lt	1	0	0	1
5/9/02 6:38 PM	69.22	-126.97	B14	off	lt	14	0	4	18
5/9/02 6:50 PM	69.22	-126.21	B14	on	rt	4	0	0	4
5/9/02 7:14 PM	69.32	-127.02	B15	on	rt	12	0	0	12
5/9/02 8:07 PM	69.41	-127.33	B16	on	rt	7	0	3	10
5/9/02 8:38 PM	69.22	-126.21		off	lt	4	0	0	4
5/10/02 9:12 AM	68.80	-125.91		off	lt	12	0	0	12
5/10/02 10:23 AM	68.28	-123.70	A04	on	lt	3	0	0	3
5/12/02 3:56 PM	68.75	-124.79	A09	on	rt	4	1	0	5
5/12/02 4:57 PM	68.86	-126.27		off	lt	6	0	1	7
5/12/02 5:55 PM	68.90	-126.23		off	rt	10	0	6	16
5/12/02 6:33 PM	68.91	-123.63	A11	on	rt	5	0	0	5
5/13/02 3:51 PM	69.83	-125.02	A21	on	lt	15	0	3	18
5/13/02 6:42 PM	69.42	-126.10	A15	off	rt	1	0	0	1
5/13/02 6:50 PM	69.49	-126.42	B17	on	rt	20	0	4	24
5/13/02 6:55 PM	69.49	-126.75	B17	on	rt	3	0	0	3
5/13/02 6:57 PM	69.49	-126.84	B17	on	lt	11	0	3	14
5/13/02 8:04 PM	69.58	-126.45	B18	on	rt	10	0	2	12
5/13/02 8:15 PM	69.67	-126.90	B19	on	lt	1	0	0	1

APPENDIX I: Caribou Observed During The Muskox Survey, May 2002.

Date and Time	Lat	Long	Transect	On/Off	Lt/Rt	Adults
5/5/02 10:01 AM	68.04	-131.20		off		50
5/5/02 10:52 AM	68.15	-128.72	C02	off	rt	18
5/5/02 1:03 PM	68.31	-130.60	C04	on	lt	12
5/5/02 1:03 PM	68.31	-130.60	C04	off	lt	100
5/5/02 1:16 PM	68.38	-131.33	C04	off	lt	2
5/5/02 1:31 PM	68.40	-130.46	C05	on	lt	4
5/5/02 1:31 PM	68.40	-130.42	C05	off	rt	100
5/5/02 2:58 PM	68.40	-132.19		off	rt	150
5/5/02 2:59 PM	68.39	-132.25		off	rt	10
5/5/02 4:10 PM	68.38	-132.93		off	rt	8
5/5/02 5:03 PM	68.60	-129.42	C07	on	lt	8
5/5/02 5:12 PM	68.60	-128.76	C07	off	lt	20
5/5/02 5:12 PM	68.60	-128.81	C07	off	rt	300
5/5/02 5:30 PM	68.69	-129.26	C08	on	lt	2
5/5/02 6:40 PM	68.77	-129.33	C09	on	lt	9
5/5/02 6:44 PM	68.78	-129.13	C09	on	rt	6
5/6/02 12:31 PM	68.82	-131.84		off		40
5/6/02 12:32 PM	68.85	-131.78		off		30
5/6/02 2:14 PM	69.10	-131.45	C13	on	rt	4
5/6/02 2:15 PM	69.10	-131.41	C13	on	rt	15
5/6/02 3:09 PM	69.23	-129.23	C14	on	lt	10
5/6/02 3:28 PM	69.22	-130.47	C14	off	rt	100
5/6/02 3:30 PM	69.24	-130.46	C14	off	rt	2000
5/6/02 3:37 PM	69.22	-130.57	C14	off	rt	600
5/6/02 3:39 PM	69.21	-130.67	C14	on	rt	600
5/6/02 3:45 PM	69.20	-131.04	C14	on	rt	600
5/6/02 3:51 PM	69.20	-131.36	C14	on	lt	25
5/6/02 4:13 PM	69.30	-130.93	C15	off	rt	16
5/6/02 4:20 PM	69.30	-130.51	C15	off	rt	300
5/6/02 5:28 PM	69.38	-130.99	C16	on	lt	155
5/6/02 5:31 PM	69.39	-131.08	C16	off	rt	12
5/6/02 5:33 PM	69.38	-131.28	C16	on	rt	9
5/6/02 5:33 PM	69.38	-131.28	C16	off	rt	18
5/7/02 2:03 PM	69.58	-129.90	C18	on	rt	5
5/7/02 2:11 PM	69.57	-130.43	C18	on	lt	12
5/7/02 2:56 PM	69.76	-129.67	C20	on	lt	10
5/7/02 2:57 PM	69.76	-129.80	C20	on	lt	6
5/7/02 3:03 PM	69.81	-129.58		off	rt	8
5/7/02 6:31 PM	69.10	-131.46		off		12
5/8/02 2:56 PM	68.47	-131.98		off	rt	25
5/8/02 3:32 PM	68.75	-129.17		off	rt	30

Date and Time	Lat	Long	Transect	On/Off	Lt/Rt	Adults
5/8/02 6:30 PM	68.69	-127.16	B08	on	rt	100
5/8/02 6:30 PM	68.69	-127.16	B08	off	rt	100
5/8/02 6:34 PM	68.70	-127.43	B08	on	lt	1
5/8/02 6:35 PM	68.70	-127.49	B08	on	lt	5
5/8/02 6:35 PM	68.69	-127.53	B08	on	lt	10
5/8/02 7:22 PM	68.60	-126.80	B07	on	lt	25
5/9/02 9:05 AM	68.27	-126.00		off	rt	50
5/9/02 10:36 AM	68.14	-126.09	B02	on	lt	16
5/9/02 10:53 AM	68.24	-126.06	B03	off	rt	20
5/9/02 11:38 AM	68.33	-128.12	B04	on	lt	45
5/9/02 11:41 AM	68.33	-127.96	B04	off	lt	4
5/9/02 11:48 AM	68.33	-127.49	B04	off	rt	15
5/9/02 11:51 AM	68.33	-127.29	B04	off	rt	15
5/9/02 12:02 PM	68.33	-126.63	B04	on	lt	5
5/9/02 12:57 PM	68.42	-128.22	B05	on	rt	16
5/9/02 1:21 PM	68.51	-127.56	B06	off	lt	2
5/10/02 12:40 PM	68.05	-125.35	A01	on	lt	25
5/10/02 2:18 PM	68.66	-126.29		off	rt	26
5/12/02 2:17 PM	68.67	-126.15		off	rt	400
5/12/02 2:20 PM	68.64	-125.99		off	rt	100
5/12/02 3:34 PM	68.68	-125.58	A08	off	rt	50
5/12/02 5:01 PM	68.84	-126.48		off	lt	20
5/13/02 11:08 AM	68.85	-126.48		off	rt	16
5/13/02 11:08 AM	68.84	-126.45		off	rt	41
5/13/02 11:10 AM	68.83	-126.31		off	rt	12
5/13/02 11:12 AM	68.82	-126.23		off	rt	12
5/13/02 11:15 AM	68.78	-125.94		off	rt	11
5/13/02 11:17 AM	68.77	-125.83		off	rt	20
5/13/02 11:17 AM	68.77	-125.81		off	lt	200
5/13/02 11:20 AM	68.76	-125.61		off	rt	30
5/13/02 11:22 AM	68.73	-125.43		off	rt	100
5/13/02 11:26 AM	68.71	-125.17		off	rt	15
5/13/02 11:26 AM	68.71	-125.13		off	rt	25
5/13/02 11:27 AM	68.70	-125.05		off	lt	25
5/13/02 11:35 AM	68.66	-124.53		off	rt	27
5/13/02 11:49 AM	68.55	-123.57		off	rt	14
5/13/02 12:03 PM	68.73	-123.72		off	lt	11

APPENDIX J: Boreal Woodland Caribou Observed During The Muskox Survey, May 2002.

Date and Time	Lat	Long	Adults	Calves	Comment
5/5/02 12:33 PM	68.33	-128.84	12	2	at least 3 antlered cows

APPENDIX K: Golden Eagles Observed During The Muskox Survey, May 2002.

Date and Time	Lat	Long	Adults
5/13/02 1:28 PM	69.27	-123.68	2
5/13/02 6:59 PM	69.49	-126.99	1
5/13/02 7:19 PM	69.50	-128.37	1

APPENDIX L: Grizzly Bears Observed During The Muskox Survey, May 2002.

Date and Time	Lat	Long	Adults	Yearlings
5/6/02 2:48 PM	69.12	-129.38	1	
5/7/02 2:30 PM	69.66	-129.55	1	
5/7/02 5:50 PM	69.67	-129.42	1	3
5/9/02 3:59 PM	68.96	-126.80	1	
5/9/02 5:27 PM	69.13	-126.10	1	
5/9/02 5:27 PM	69.13	-126.12	1	
5/9/02 7:21 PM	69.32	-127.51	1	
5/9/02 8:35 PM	69.26	-126.13	1	
5/12/02 7:35 PM	69.11	-124.97	1	
5/12/02 8:03 PM	69.17	-123.45	1	
5/13/02 2:06 PM	69.39	-125.43	1	
5/13/02 2:07 PM	69.39	-125.38	1	
5/13/02 2:26 PM	69.47	-124.50	1	
5/13/02 4:12 PM	69.98	-124.46	1	
5/13/02 6:44 PM	69.45	-126.18	1	
5/13/02 8:08 PM	69.65	-126.51	1	
5/13/02 8:19 PM	69.68	-127.10	1	

APPENDIX M: Moose Observed During The Muskox Survey, May 2002.

Date and Time	Lat	Long	Adults
5/5/02 5:17 PM	68.63	-128.51	1
5/10/02 12:51 PM	68.04	-124.65	1
5/13/02 8:35 PM	69.68	-128.11	3

APPENDIX N: Wolves Observed During The Muskox Survey, May 2002.

Date and Time	Lat	Long	Adults	Comment
5/7/02 1:06 PM	69.46	-131.26	1	near 2 red foxes
5/12/02 3:20 PM	68.66	-124.66	1	dark

APPENDIX O: Wolverine Observed During The Muskox Survey, May 2002.

Date and Time	Lat	Long	Adults	Comment
5/5/02 6:42 PM	68.78	-129.19	1	
5/6/02 3:07 PM	69.23	-129.15	1	
5/6/02 3:42 PM	69.21	-130.79	1	
5/12/02 5:57 PM	68.92	-126.06	1	light coloured